(see p. A4, footnote 3 in PageMart's Petition for Rulemaking). Fortunately, cellular telephone users with the millions of hand held portable phones prove every day (and have proven since the mid-80's when cell sites were not as dense as they are today) a 0.6 watt return link can function effectively in the car and even in many buildings.

Consequently, MPR results that indicate...

> "Calculations indicate that for a 0.1 watt subscriber device, between 25 and 169 dedicated receivers per base station cell site would be required"

... is totally incorrect. Based on the aforementioned table of available power levels, PageMart's 10 watt inbuilding power module and 0.1 watt subscriber transceiver module (STM) for free space would be preferred to a two-watt transceiver used for both inbuilding and free space (and cellular's 0.6 watt portable hand held units are physical evidence of this). Furthermore, as experimental evidence is evaluated, STM transmitter power could be increased (even up to 1 watt). Moreover, given the published literature in this field, a literature search shows that the key factor in Dr. Lee's propagation model is the distance equation ($38.4 \log_{10} D_1$). Depending upon the researcher and the objective of the study, one can find the equation to vary widely:

- $38.4 \log_{10} d_1$ - MPR's equation (ref. Okumura, 1968)
- $20 \log_{10} d_1$ - Bullington, 1977 (medium range portion)
- $20 \log_{10} d_1$ - Harley, 1989 (short range)

The range difference between the log-log slope of 38.4 versus 20 can vary substantially and can easily double the range available in calculations under 10 miles. The plain fact is that PageMart's PIMS low power solution is free space (and 10 watts inbuilding) out performs MTel's two-watt only solution. The more appropriate issue, then, is the problem with MTel's transceiver using one power source for all applications, (MTel should then reconsider their 7 watts "die hard" battery solution to be only on a par with PageMart, because they will lose another 3 dB if one compares MTel's 9,600 bps return link to PageMart's 4,800 bps return link solution).

> **MPR states inbuilding transmission creates serious problems of cochannel and adjacent channel interfaces.**
>
> "The use of 1 Watt and 10 Watt transmitters for in-building transmission creates a serious problem of cochannel and adjacent channel interference for users outside the building and in adjacent building towers. This is based on the false assumption by PageMart that building walls offer high levels of signal attenuation."

PIMS' approach is to contain the inbuilding RF by transmitting only that level of RF needed for reliable inbuilding data transmission. First, the PIMS approach creates the opportunity to realize massive amounts of frequency reuse through low-cost, PC board-type interface and transceiver modules that would be readily interfaced to a standard DOS-type PC (including modem). MPR's own recognition of this is cited in their paper were, if not for the maximum ERP power levels, assumed by MPR (page 16):

> "Although the concept proposed by PageMart is attractive on the surface, there appear to be some fundamental problems in the areas of propagation and building attenuation which have not been fully addressed. The concept proposed would work well if buildings could be considered as perfect RF enclosures, but the vast majority of buildings cannot be treated as such."

PageMart proposes a <u>maximum</u> ERP of 1 watt for inbuilding office cells because there is a great potential difference between offices, both as to location, size and in some cases, an office cell may be used more like a building cell in manufacturing and processing plant environments. It's surprising that MPR would miss the obvious point that each class of installations, such as high rise office buildings (urban areas), versus stand-alone buildings (suburban areas) and the square feet to be covered by the office cell must all be considered so that the lowest acceptable power level is used in any given class of application, because the objective is to contain the RF energy to the extent practical, within the building. Since the PIMS operator(s) would be the source of office and building cell equipment and installation, the inbuilding RF environment will be properly engineered and managed.

Typical power levels from the significant experience of CT-2 installations around the world indicate that ERP levels range from approximately 0.005 to 0.01 watts per channel in most "office environments" (Exhibit 6). PageMart would operate at similar levels.

PIMS broadcasts only non interfering geographical cells during a building/office cell time segment. The same MPR transmission loss equations indicate a calculated value of 0.25 miles distance or two city blocks (and not 0.85 miles) for 0.01 watts ERP which is further reduced by the insertion loss due to other neighboring buildings. The key issue is that a PIMS office cell or building cell does not transmit (1) at maximum ERP unless the nature of the building requires the power, or (2) generate cochannel interference with an overlapping geographical cell, because only non-interfering geographical cells are broadcasted during a building or office cell time segment (see PageMart Rulemaking document p. A22 and Exhibit X). Consequently, geographical cells are not broadcasting in areas where there are building and office cells in order to provide for the massive frequency reuse possible through inbuilding cells. Thus, there is never "an on-street subscriber device" 'that' could still receive signals form this office cell at a distance of 0.85 miles" (page 15, MPR) because a subscriber on the street does not have the possibility of a geographical cell broadcasting in that area on the same time segment.

MPR goes on to conjecture that office cells could interfere with another in an adjacent building, even though "in this case, the RF radiation passes through two building walls (at least)" (page 16, MPR). Using MPR's own conclusion, this is equivalent to 2 X 15 dB = 30 dBm, plus attenuation due to distance, at ground levels (and less as building attenuation decreases with building height) and will not pose any problem with normal inbuilding radiated power of 5 to 10 milliwatts ERP any more than garage door openers and CT-1 cordless phones would create a major problem in suburban areas.

From the standpoint of building cells, the same mistake is made by MPR to use the maximum rated ERP in all building applications without engineering the RF environment in the building. Once again, for purposes of RF containment, building cells will be maintained at as low a power level as practical (typically under 0.1 watts radiating in the mechanical building core) so as not to create unnecessary building-to-building cochannel interference. The output of an inbuilding-distributed antenna system such as that depicted in the PIMS Rulemaking document would require distributed amplifiers to compensate for losses encountered in using a slotted coaxial cable that is hung in the mechanical building core of high rise office buildings. Alternatively, the Decibel Products (DP) solution of a distributed antenna network using 75 ohm coaxial cable with amplifiers would not require high input power at the base station (see Exhibit 7). The DP approach has the added advantage of managing each distributed antenna's output at (1) very low levels of ERP (0.005 to 0.01 watt, and (2) focuses the directional antenna pattern at the interior of the building for even greater RF containment.

Therefore, building cells can be engineered to effectively contain the low levels of RF energy broadcasted. Moreover, there is no cochannel interference when PIMS controls the time of broadcast for building and office cells separate from geographical cells in that local area.

MPR states that PIMS transmitter will jam themselves.

> "There is a great deal of concern about the high power base stations presenting unacceptable levels of adjacent-channel interference in the system coverage area. It appears that they could jam themselves as well as subscriber devices near the base sites."

PIMS base station sites will be engineered to avoid receiver desensitization. First of all, the adjacent channel problem MPR refers to applies more to MTel's NWN system for in-band (930-931 MHz) problem because they will not be able to manage any of the adjacent 50 kHz channel(s) whereas, in PIMS 10-25 kHz channel groups, PageMart and other PIMS system operators can manage the adjacent, in-band, channels (10 channels) to a much higher degree. The out-of-band 929-930 and 931-932 MHz issue has already been addressed by PageMart in the PageNet comments (see PageMart Reply Comments, June 16, 1992, page 19-21). Furthermore, MTel's Reply Comments, June 16, 1992, page 10, footnote 20 also addresses the same adjacent channel interference problem MPR now raises for PageMart. However, the specific advantage MTel claims with NWN that...

> "...the return signal will use a relatively narrowband (25 kHz) channel operating at 9.6K bps that is embedded within the 50 kHz channel. The built-in guardband affords at least 20 dB of additional protection"

...is unlikely.

What is likely is that in order to suppress a 900 MHz signal by 20 dB, (that is, 12.5 kHz from the carrier) would require at least a fourth order filter with loaded Q's of 37.2K. In simple numbers, the roll-off of a single-tuned circuit is 6 dB/octave; therefore, it would take at least a fourth order Butterworth circuit to acquire 24.3 = 21 dB isolation. This would set the undamped resonate frequency at 12.5 kHz or a band pass value of 25 kHz. At 930 MHz, this would reflect a loaded Q of greater than 37,200 or a very large physical filter at 930 MHz.

> **MPR states the PIMS subscriber transceiver module must be powered up for long periods of time.**
>
> "The requirement on the subscriber device to measure the signal strength of the polling channel for the base sites requires that the subscriber device be powered on for long periods of time. This will drastically reduce the battery life."

PIMS subscriber transceiver module is as power efficient as a pager in the receiver mode. The simple answer (see page A8,9, PageMart Petition for Rulemaking) is that PageMart's novel "best serving transmitter identification" (TXID) approach means that the subscriber unit does not have to be on all the time to measure signal strength (as in conventional cellular telephony). The subscriber transceiver module (STM) can receive a broadcast in its designated frame, power down thereafter and store the TXID for later broadcast back to the system controller (standard POCSAG paging receiver operation is that after the receiver acquires sync it only powers up one out of eight frames to decode address). Therefore, the STM does not need to have a scanning receiver nor does it need to measure signal strength but, due to frequent, periodic base station transmitter broadcast, it can move between serving cells and always be in a position to monitor its best serving transmitter and relay this information (TXID) to the system controller (via the return link receiver network) when a message notice or poll is received.

As a result, no such "drastic" reduction in battery life as anticipated by MPR is relevant.

MPR concludes that NWN's Time Division Duplex (TDD) is less susceptible to adjacent channel interference than PIMS.

> 'Since the PageMart system is not Time Division Duplex, they are susceptible to adjacent channel interference from other units operating within the system on the polling, return link and data channels. It has been shown that destructive adjacent channel interference extended up to 0.5 miles from each base station site."

PIMS has less adjacent channel interference than NWN's TDD solution. PIMS, with its cellular approach, will manage its maximum forward link transmission power in order to optimize the balance between minimizing the number of base stations and maximizing desired cell coverage with the objective of maximizing the number of cells for high data throughput. Therefore base station ERP will likely be limited to less than 500 watts in dense urban areas whereas the simulcast solution of NWN will be motivated to have as few transmitter base stations as possible (as Sky Tel does now for its nationwide paging service) with each operating at or close to maximum power (3,500 watts ERP in the NWN petition). Therefore the other NWN carriers will potentially create a far more significant adjacent channel interference using TDD (simulcast) than PIMS' operators managing ERP with respect to frequency reuse.

The main objective is site engineering the forward link transmitter channels and the return link receiver channels as discussed in PageMart's Reply Comments. (June 16, 1992, p. 19-21). MTel's NWN being a TDD, non-trunked-single channel approach cannot exercise any control over adjacent channel forward link versus return link cycles of other carriers (i.e. NWN is in a receive cycle and other adjacent carriers are in a transmit cycle). However, the more relevant issue is the out-of-band RF problems from the PCP and RCC paging band which, MTel has apparently not yet addressed but PageMart has. Therefore, the claim made by MPR that "MTel avoids this problem by using TDD transmission scheme" is incorrect.

MPR claims that PIMS must use a high cost DSP chip/receiver.

> "...to achieve higher data rates in their system, PageMart will not be able to use low cost subscriber devices. Complexity comparisons with similar speed devices has shown that they will require higher cost DSP, discrete analog/digital or custom VLSI implementations."

PIMS will not be forced to deviate from a conventional receiver design or use a DSP chip at 4800 or 6250 bps. The assertion by MPR that the PIMS transceiver requires high-power components to operate at 4,800 to 6,250 bps is wrong. Processing of digital signals doesn't necessarily imply the use of a Digital Signal Processing (DSP) chip. DSP's are used primarily for a subset of digital signal processing, such as TI's chip to emulate a classical filter design, digitally. In fact, it finds many applications in many RF receiver designs, such as satellite receivers that PageMart uses to control each individual base station and thereby eliminate the need for control channel spectrum.

Even very high speed receivers cited by PageMart in its Reply Comments June 16, 1992, to MTel indicates that a simple phase lock loop (PLL) design can support a "high-speed" data rate of 16K bps in a 25 kHz bandwidth.[11] However, what seems more apparent is that MPR, with its multi-level signaling scheme,

[11] May 1980 IEEE. On a Method of Constant Envelope Modulation for Digital Mobile Radio Communication. Kouichi Honma, Eiichiron Murata, Yasuhiro Rikou Matsushita Communications Industrial Co., LTD. 16,000 bps in a 25 kHz channel that meets FCC masking requirements using PSK modulator and PLL circuit.

feels that it must resort to a DSP chip design for signal enhancement of its complicated multi-tone signaling scheme.

It is NWN that has the feasibility and cost issue with its yet-to-be-proven-and-tested modulation design, not PageMart. PageMart's design is well along in the PCMCIA card configuration with a first generation 2400 baud POCSAG receiver (see Exhibit 8). Adding a conventional transmitter circuit is also underway for the transceiver card.

MPR concludes that PIMS is limited to 3,000 bps.

> "There is considerable doubt that PageMart can achieve 4,800 bps rates on its polling channel, and they would be limited to rates no higher than about 3,000 bps."

PIMS is not limited to data rates less than ERMES. First of all, we do not believe MPR means 3,000 bps but 3,000 baud. Second, PageMart has not restricted its modulation alternatives (see page A26 in PageMart's Petition for Rulemaking), but to the contrary, takes the position that its tremendous improvement in throughput comes from its novel cellular architecture and not a very high speed modulation scheme. Therefore, it can be flexible in adopting various manufactured products incorporating the ERMES receiver chip set when it becomes available.

The fact is that major manufacturing suppliers to the paging industry are poised to provide high-speed coding capability to make another major step forward. Whether this is 4 FSK (as ERMES) or other modulation techniques, PageMart's system doesn't need "blinding speed" as MTel <u>must</u> have to realize a significant increase in data rate because, <u>at best</u>, NWN represents a <u>simulcast</u> paging system from a network capacity standpoint.

Also, it is difficult to understand why MPR does not believe that the European modulation standard (ERMES) is feasible or cannot practically be implemented to achieve 6250 bps. It is particularly difficult to understand their position on ERMES when they support as feasible, the 24,000 bps data rate of NWN. Finally, the 3,000 baud limit is more a self imposed limit justifying the complex modulation approach used in NWN, since there is no hard evidence to support their 3000 baud limit claim and even one of the AMS petitioners, PacTel, states that it has "discerned that the simulcast boundary for near term development is between 3200 and 6400 baud based on its experiments" that appear to be more advanced than MTel's paper studies (see June 1, 1992, PacTel's Supplement to Request for Pioneers Preference, p. 3).

MPR states:

> "The spread in time delays between these received signals at the portable is the "simulcast time delay spread." Simulcast transmitters up to a distance of 3.6 times this distance from the base station, or 15.4 miles, result in the maximum delay. The minimum delay occurs for a portable terminal near the cell site transmitter. Thus simulcast delay spread will be the order of 83 microseconds."

To demonstrate the error in MPR's conclusion, suppose the issue of finding the equi-signal strength "points" between two adjacent transmitters "wanders" around approximately 7.5 miles or 15 miles in total deviation which is MPR's 80+ microsecond delay spread. Now, if the two transmitters in PageMart's PIMS system were located 15 miles apart or less (center-to-center distance, which is typical in 900 MHz paging), then this would suggest that the total equi-signal strength point deviation would wander from one base station site to the other or 15 miles. Simply put, this does not happen. It is even less likely given the motivation to create an even greater number of base station sites or cells in the PIMS system relative to a conventional paging system. Thus, the total deviation of the equal signal strength "points" is crucial to the bold and unfounded statement by MPR that the 3000 baud rate is the upper limit and totally unrealizable in actual practice.

Finally, there is every reason to believe that the European paging standard, ERMES, will also be implemented in the U.S. similar to POCSAG, and that ASIC technology will quickly advance to encompass 4 FSK modulation into very low-cost receivers as has been characteristic of the paging industry. Thus, the comments stated below by MPR (page 26) are totally false and misleading:

> PageMart is almost two-thirds greater than this rate, which would indicate that the 4,800 bps polling channel rate will provide a marginal degree of operation even if it could operate at all. Lowering the data rate to something the order of 3000 baud would appear to be required. Attempts to increase the polling channel data to 9600 baud or higher does not appear to feasible in the type of system proposed by PageMart.

Once again MPR continually mixes bps and baud since PageMart stipulates bps not baud because PIMS can accommodate any type of modulation approach which will have desired data rate, power and cost performance. There is no question that PIMS can technically achieve a proportionate data rate in a 25 kHz channel that MTel can achieve in a 50 kHz channel, given Shannon's law in information theory.

MPR claims that PIMS is a Mobitex look-alike.

> "The PIMS system proposed by PageMart is very similar to the Ericsson Mobitex system currently operated in Sweden, Norway, Finland and Canada. This system equipment is also used by RAM Mobile Data Ltd. in their nationwide mobile data network in the United States. Thus it is hardly advanced in nature, nor is it the first system of its type."

PIMS is a novel cellular paging type architecture. MPR does not understand PageMart's PIMS proposal. It is common knowledge that the Mobitex packet radio network is a two-way, real time, interactive, data network system requiring channel pairs (MPR, page 23). PIMS is a two-way, non-real time, non-interactive data network. Therefore, the similarity ends at the two-way portion of the comparison. The tremendous advantage of PIMS lies in the combination of the novel use of simulcast paging technology for radio locationing, the use of cellular frequency reuse principles for massive improvements in throughput and the innovative notion of utilizing very low-power/low-cost office cells and high rise office building cells to significantly enhance reuse (similar to future PCS voice proposals). Therefore, the similarity is that both Mobitex and PageMart take advantage of frequency reuse, but the comparison ends there (not in the long list of features).

The fact that both Mobitex and PIMS both utilize multiple frequencies for trunking efficiencies has to do with the recognition that any high throughput system that wishes to achieve full economies of scale will design a wireless system to take maximum advantage of the investment at each cell site. This "spreading" of fixed site cost cannot be done with a single channel system, such as MTel's NWN. Moreover, NWN requires a two-way network of receivers but cannot take practical advantage of cellular reuse within contiguous urban areas due to destructive cochannel interference[12] because it operates on one channel. Unfortunately, it is the major cities where the vast majority of subscribers will be for AMS services.

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[12] MTel proposes a dynamic zoning method to increase capacity but never explains what improvement it would make. Also, it never fully explains dithering and how it can accomplish dynamic zoning with a mobile customer base.

B. Comments on the Data Link Layer Aspects of the PageMart Petition for Rulemaking.

MPR asserts that PIMS' polling channel limits capacity to an order of magnitude less than proposed.

> "The simulcast polling channel, used for radiation and data channel assignments, is a constraining factor in overall system capacity. Using PageMart's message model, the best case scenario could support no more than 3000 messages per hour, the equivalent of 12,000 subscribers per MSA. This is an order of magnitude less than the 100,000 to 200,000 subscribers claimed for a 4800 bps system."

PIMS' polling channel doesn't limit proposed capacity. MPR redesigns PIMS' Acknowledgment process so that the entire polling channel is consumed with the task of polling following acknowledgment to re-establish the packet circuit it has already established, rather than the polling channel being used <u>as it was intended,</u> namely for location of the subscriber transceiver module (STM) as to its best serving transmitter (TXID). MPR confuses the error protection and acknowledgment process with the purpose of the polling channel to locate the STM.

> **MPR:** "For error protection reasoning, PageMart has decided to segment messages into packets of "2 to 5 POCSAG batches." The implication is that each data packet must be assigned a data channel via the poll channel protocol, because each packet is individually acknowledged and retransmitted if required, which would require 30-75 transactions on the poll channel. Best case, the, the poll channel could handle the equivalent of 3000 average size data messages per hour, assuming a 5 batch packet length. At a 2 batch packet length, this decreases to 1200 data messages per hour."

Once the polling channel has located the subscriber transceiver module's best serving transmitter identification (TXID), its job is done. The return link and serving transmitter form a packet network that is maintained until the acknowledgment process ceases to function (i.e. the battery failed). Simply getting an ACK or NAK does not reactivate the polling link.

"Moreover, in reviewing the three versions of ARQ in popular use,[13] "none of the techniques listed below would require a reactivation of the polling channel:

1. **Stop and Wait ARQ** uses the simple stop-and-wait acknowledgment scheme. The sending station transmits a single frame and then must await an acknowledgment. No other data frames can be sent until the receiving station's reply arrives at the transmitting station. The receiver sends a positive acknowledgment (ACK) if the frame is correct and a negative acknowledgment (NAK) otherwise."

2. **Go-back-N ARQ is one variant of Continuous ARQ.** In this technique, a station may send a series of frames determined by window size. If the receiving station detects an error on a frame, it sends a NAK for that frame. The receiving station will discard all future incoming frames until the frame in error is correctly received. Thus the transmitting station, when it receives a NAK, must retransmit the frame in error plus all succeeding frames.

   With go-back-N ARQ, it is not required that each individual frame be acknowledged. For example, station *A* sends frames 0, 1, 2, and 3. Station *B* responds with ACK1 after frame 0, but then does not respond to frames 1 and 2. After frame 3 is received, *B* issues ACK4, indicating that frame 3 and all previous frames are accepted.

3. **Selective repeat continuous ARQ** provides a more refined approach than go-back-N. The only frames retransmitted are those that receive a NAK. "As an example, if in a long message transmission" only frame 2 need be retransmitted. This would appear to be more efficient than the go-back-N approach. On the other hand, the receiver must contain storage to save post-NAK frames until the error frame is retransmitted, and the logic for reinserting the frame in the proper sequence.

PIMS intends to use a continuous ARQ approach. Although as previously mentioned, none of the ARQ approaches mentioned above must re-establish the original "handshake" in the event of any ACK/NAK acknowledgment which MPR has assumed in their analysis of PIMS to drastically reduce polling channel capacity (page 3). The implication of MPR's implied redesign of PIMS is that each data packet must be assigned a data channel via the polling channel

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13 Handbook of Computer Communications Standards - Volume I, William Stallings, Stallings/MacMillan, 1987.

protocol, because each packet is individually acknowledged and retransmitted if required, which would require 30-75 transactions on the poll channel). Therefore, the MPR, inappropriately coupled with a channel utilization factor to reflect actual operation, reduces PIMS' polling channel capacity by a factor of 37.5 is entirely wrong. Acknowledgments are made in the reserve synchronous time slots of the return link (see A15, Exhibit XV, PageMart Petition for Rulemaking). Therefore a continuous packet circuit is established that does not require any additional handshake via the polling channel irrespective if ACKs or NAKs are received.

PIMS' control channel can support 450,000 subscribers at 4800 bps. MPR is approximately correct (assuming the need for preamble) by arriving at 112,700 poll (and Go To channel) transaction per hour at 4800 bps or 225,400 transactions per hour at 9,600 bps. Using the above MPR assumptions and a continuous ARQ approach previously discussed, the following is a table of results:

Theoretical Control Channel Capability

	Transactions Data Rate	Per Hour	Reduction due to to Polling Channel Handshake/Packet	Utilization Assumption	Net Transactions Per Hour	**Total Subscriber Capacity**
MPR	4800	112,700	1/30	80% (Incorrect)	3,000	**12,000**
PageMart	4800	112,700	none(Continuous)	NA (Theoretical)	112,700	**450,000**
PageMart	9600	225,400	none(Continuous)	NA (Theoretical)	225,400	**901,600**

Therefore, the actual poll transactions are 37.5 times (greater than) that calculated by MPR which in turn has a critical impact on PIMS subscriber capacity. The actual theoretical capacity of the polling channel is over 450,000 subscribers per MSA at 4800 bps to over 900,000 subscribers per MSA. It should be noted that in NWN's scheme, both ACK/NAK and registration (automatic and manual) and retransmission (particularly if dynamic zoning is used) significantly reduces throughput of their system and that elaborate schemes of auto identification to avoid this problem have been devised, but not confirmed, (page 10, Exhibit E, Technical Feasibility Demonstration by MTel, June 1, 1992), could be extremely costly.

MPR asserts that if inbuilding cells are deleted and 9 cell reuse is required, data channel capacity is reduced.

> "Each data channel can support no more than 600 subscribers. Total system capacity is dependent on implementing a large number of non-interfering cells, subject to the limits of the poll channel."

Inbuilding cells are in commercial operation today and 4 cell reuse has been validated by MPR's own authoritative source. Three major issues are to be made with MPR's analysis. First, the estimates do not include any building cell or office cell reuse, therefore, MPR has again redesigned PIMS to reduce it to <u>having the same major deficiency as NWN</u>, namely no provision for significant messaging service in buildings, yet that is where AMS is intended to reach business people most of the time. NWN would appear to be optimized around the conventional paging paradigm of meeting the needs of service people and tradesmen that do not have offices but frequently work on maintenance or construction projects in and outside office buildings, homes, etc.. PageMart believes that AMS requires highly efficient use of spectrum given that business people will be in offices as well as mobile, and not to take advantage of low cost messaging services, using PC-based office cells, given the present explosive growth in highly portable, personal computers is to ignore current trends and future forecasts (Exhibit 9). Second, MTel continually refers to its nationwide system capacity of 800,000 subscribers (with an early estimate of 34 zones now increased to 57) which implicitly assumes maximum theoretical data rate capacity in most all the major cities, not actual or estimated capabilities based on practical data throughput. Third, a 9 cell reuse pattern is assumed for PIMS that is irrelevant given our earlier comments on the physical layer critique by MPR.

The following table provides the comparison of PIMS "capacity" as determined by MPR and PageMart.

Data Channel Capacity Comparisons (Major MSA)

			Geographical Cells Only			Geographical Building/Office Cells		
Analysis	PIMS Phase	Data Rate	Concurrent Data Channels	Theoretical Capacity	Actual Capacity	Concurrent Data Channels	Theoretical Capacity	Actual Capacity
MPR	growth	4,800	80		34,000			
MPR	growth	4,800	35.6 (9 cells reuse)		15,000		(ignored)	
PageMart	growth	4,800	80	65,000	35,000	246	202,000	109,000
PageMart	growth	9,600	80	130,000	70,000	246	404,000	219,000
PageMart	mature	4,800	120	98,000	52,000	556	457,000	243,000
PageMart	mature	9,600	120	197,000	104,000	556	914,000	486,000

Therefore, simply because NWN's architecture cannot accommodate office and building cells, MPR elected to ignore PIMS' capability to do so. This is entirely inappropriate and self serving for comparison of PIMS with NWN.

MPR claims the return link channel cannot work as described.

> "The return link media access protocol cannot work as described. The information content of the required messages cannot fit within their allocated time slots, and no allowance has been made for real-world device characteristics in terms of timing, synchronization and turn-on times. A realistic return link protocol would restrict the poll channel transaction rate even further, reducing system capacity accordingly."

PIMS' control link channel functions as proposed with one code word. MPR first redesigns PIMS with an arbitrary assumption that leads to an immediate reduction in return link capacity by a factor of 37.5. MPR, in its redesign of PIMS, requires the subscriber transceiver unit to acknowledge with its "cap code" address as well as (1) the best serving transmitter identification, and (2) message disposition. so that the return link information will exceed the 20 data bits per frame available in POCSAG format, when MPR knows the polling channel and return link channel is synchronized and doesn't require subscriber identification to complete a poll.

MPR states on page 4 and 5 that they are aware that the return link channel is time-synchronized to the polling channel:

> "The return link channel is time-synchronized to the poll channel and uses POCSAG batch formatting."

MPR then goes on to state on page 5 that PIMS doesn't need to transmit cap code address in a synchronized system <u>but never reflects this result</u> in its polling channel capacity calculations:

> "Alternatively, the device's POCSAG address may not need to be transmitted, since the system knows which device's response is expected, albeit at a cost of increased complexity in the network processing."

In fact, the entire review of (1) Poll Channel Capacity, (2) Data Channel Capacity, and (3) Return Link Media Access Protocol is a totally unnecessary. The fact is that the Return Link channel has 20 bits of data available and this is more than enough for the best serving transmitter identification (TXID) in each market (excluding office cells) and short message disposition code. Since 10 bits are still available, we proposed also transmitting cap code address, in an abbreviated form, as a reliability check <u>but it is not required at all</u>. The following table describes the bit requirements currently envisioned for each type of transmission:

<u>PIMS Return Link Message Format</u>

Mode	Transmitter ID(TXID)	Subscriber Cap Code	Message Length	ACK/NAK Message #	Message Disposition	Totals Bits Code Words
Message Response	7	10*	-	-	3	**20 Bits 1 code word**
ACK/NAK	-	10*	-	10	-	**20 Bits 1 code word**
Access (for data channel)	7	18	5	-	-	**40 Bits 2 code words**

*** Optional**

MPR's analysis is flawed because they erroneously come to the conclusion that PIMS must transmit the complete POSCAG address when they have concluded it is unnecessary (see page 5). MPR states:

> "There are several problems with the return link protocol as described. First, the radio location poll-response is specified to contain the "base station ID or call sign, and its POCSAG address plus the disposition of this message." This will require a response of at least two codewords minimum, possibly three or four, depending on length of the base station ID (Page A9 implies the base station ID is one frame (2 codewords) in length). Thus, the poll response cannot be transmitted within its reserved time slot and the maximum poll rate of the system must be reduced (and thus maximum system capacity) to reserve adequate return link time for poll responses."

Since it is clear from the previous table that only 10 bits are needed (transmitter ID plus message disposition) and not 20 bits for 1 codeword, MPR criticism of the poll response is completely incorrect.

Similarly, MPR's criticism below of PIMS ARQ response is equally unfounded, given the need to likewise transmit only 10 bits including ACK/NAK plus the identify of the packet containing the error:

> "Second, a similar problem occurs for the ARQ response and for the random access slots. The ARQ response message is also likely to require two codewords to encode the device's POCSAG address. ACK/NAK status and message number (required for duplicate

detection/elimination). The data channel reservation request "indicates the message length to be transmitted, the serving transmitter site identification and the subscriber unit identification", which would require anywhere from 2-4 codewords, depending on length of base station id.

Thus, none of the return link channel messages will fit within the time slot allocated for their transmission."

Therefore, once again, only 10 bits or one code word is needed to provide the necessary response in a synchronous system in an ACK/NAK mode. In addition, the STM's ACK/NAK is synchronized in one trailing frame following each packet which is intentionally left blank in the data channel.

It is further interesting to note, that MPR attempts to find some problem with the error correction with PIMS when MTel specifically requested of MPR that NWN not be analyzed and recognized the non critical nature of this exercise that they unsuccessfully attempt to highlight with regard to PIMS (page 17, Final Report on NWN Protocol):

> "Any error protection scheme is a tradeoff of efficiency, complexity and probability of error. MTel's proposed protocol also utilizes ARQ, where messages with errors that are uncorrectable and retransmitted. These retransmissions obviously decrease the effective throughput of the channel and add to the overhead. The resulting "wasted" capacity is a function of the expected message success rate and the maximum number of retransmissions that will be attempted before discarding the message as undeliverable. <u>At MTel's request, the effect of retransmissions was not analyzed</u>. A realistic traffic model for message success rate has not been developed. Note, however, that many retransmission algorithms exist that minimize retransmission overhead, such as polling the device on non-acknowledgment rather than retransmitting immediately. These and other techniques are under review."

MPR further states that they are not familiar with a transceiver design that can turn on and off even in a synchronous system in the bit intervals that PageMart require (implied at 4800 bps). MPR states as follows:

"However, the more serious problem is that the return link media access protocol as described can not be implemented in real devices in a cost-effective manner. Back-to-back single codeword transmissions from different subscriber devices are required, with absolutely no time allocated for preamble, word synchronization or guard time between transmissions. This would require the simulcast transmitter network, all dedicated and co-located base receiver sites and all subscriber devices to be synchronized to each other within fractions of a bit interval. It would mean, for example, a system-synchronized clock would have to be distributed to all receiver sites, whether at co-located base stations, dedicated geographic receivers, building or office cells.

Even assuming such clock synchronization were economically feasible, allowance must still be made for the non-zero transmitter turn-on and decay times in the subscriber transceiver module. Fast attack and decay transceivers would significantly add to the cost of the STM, especially since they must be frequency agile as well.

To eliminate this <u>non-realizable requirement for perfect synchronization</u>, the return link protocol must be redesigned to allow for reasonable attack, synchronization and decay times, as well as expected message lengths. A reasonable conjecture might be to allow an additional codeword interval per return link message to allow for preamble, sync and guard intervals."

The aforementioned "non-realizable requirement for perfect synchronization" is completely incorrect. To address this issue, we will consider the step response of a composite RF filtering circuit consisting of nominal Q values of 100. Therefore, the equivalent low pass LaPlace transfer function equation of that passive network is.[14, 15]

$$F(s) \approx \frac{K}{(T_n S+1)^k}$$

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[14] Daniel Graupe, <u>Identification of Systems</u>, Van. Nostrand Reinhold Co., 1972. pp. 64-66.

[15] Strejc, V. Approximate Determination of Control Characteristics of an Aperiodic Response Process. Automatism, March 1960.

where, $T_n = 1/W_n$ the 3 dB response frequency of the equivalent base band circuit; and, $Q \approx W_o/W_n = 100$ (where W_o = carrier frequency); then, $W_n = W_o/100$; or $f_n = f_o/100 = 930\text{ MHz}/100 = 9.3\text{ MHz}$.

Thus, Tn = 17.11 nanoseconds/radian;

or, Tn = 107.53 nanoseconds/cycle

Now simple RC circuit analysis the rise time of an RC single root circuit is 2.2 RC or it takes 2.3 time constants to arrive at the 90% final value point. Therefore, it would take 2.3 x 17.11 = 39.35 nanoseconds for a single tuned circuit at 930 MHz (with a loaded Q of 100) to build up to the 90% final value. Hence, 2 to 4 cascaded tuned circuits would yield an elapsed response of less than 0.1 microseconds. <u>Consequently, the rise time (and decay time) is less than 0.05% of a bit interval time</u>. Thus, the "fast attack" circuit that MPR finds is a "non-realizable" requirement is <u>entirely achievable</u>.

MPR states that channel access protocol severely limits capacity.

> "The inbound data channel traffic capacity is severely hampered by the design of the channel access protocol. In the best case, inbound traffic can not exceed one-sixteenth of the outbound traffic, based on number of messages."

PIMS random access protocol permits up to 100 times greater subscriber access than NWN. First of all, PIMS has 8 frames per batch cycle which occurs on alternate batch cycles to accommodate a higher <u>throughput</u> of subscribers wishing access to a data channel than if the PIMS simply allowed all subscribers to sync-up to the random batch access interval and broadcast their request for data channel on a slotted ALOHA basis. MPR focuses on the probability of accessing a channel under conditions where a large base of subscribers all wish to make a request for a date channel reservation rather than a PIMS' ability to accommodate a factor of 8 higher throughput than single time slot (on a single channel).

MPR goes on to state:

> "Random access is just that, random, and constraining the choice of slots to different segments of the population does not affect the probability of collision once the size of the population outweighs the number of available slots."

However, its not the probability of collision that we're interested in, but the subscriber access throughput to reserve a data channel for a return data channel transmission. For example, a gas station with 8 pumps and 8 queues handles more customer throughput than 1 pump and 1 queue even though all eight lines may be equally long. However, the probability of obtaining pump service from a "random queue" in the aforementioned example is approximately the same (or probability of collision). Therefore, PIMS' throughput is the issue, not the probability of collision. Note that PIMS offers subscribers access to the return link on alternative batches. This works out to give PIMS between 50 to 100 times the access NWN affords their customers because NWN offers a 7+ millisecond time slot after each message, and also must set aside time for ACK/NAK. Thus, long messages could deny access to many subscribers while building long queues.

Furthermore, PIMS does not simply perform as a slotted ALOHA manner as MPR states:

> "One-fourth of the total return link is dedicated to this function and is accessed in a slotted-ALOHA manner."

The correct concept is multiple slotted ALOHA <u>with capture</u>. The difference is between maximum channel throughput efficiency of 37% per slot (frame) and

57% per slot with capture.[16] Thus, with subscriber units at varying distances from each return link receiver site, some collision will not occur because certain receiver sites will capture based on the strength of one STM over another. Also, because of the distributed nature of the STM's population throughout a city, further reductions in collisions will result given the spatial dispersion of STMs to receiver site groups.

MPR states their concern about PIMS' turn-on and turn-off time interval in a cellular system that has mutually exclusive channel assignments of its adjacent cell. The separation between non-overlapping cells provides adequate isolation in the "key down" overlapping with a "key up" transmitter at least one cell removed. MPR states the following:

> "PageMart proposes two alternatives to transmitting the base station call sign. In the first alternative, "one geographic cell, in each four geographic cell group, is to broadcast its station identification in each frame for a designated batch. During this batch, the other three geographic cells simply broadcast the sync pulse and power down". Presumably, these high powered transmitters will be able to power down instantaneously, and power up again instantaneously, so as not to interfere with the call sign transmission of the neighboring cell. It also implies that the signal strength measurement is to be taken during this interval, during the normal wakeup period of the subscriber device, i.e. 2 codewords or 13.3 milliseconds."

One has to wonder what the overlap problem might be, however, in a TDD system such as NWN where significant inefficiencies may be required to achieve

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[16] Distributed Telecommunication Networks, Roy Rosher Lifetime Learning Publication (Wadsworth Inc.) 1982. The analysis of the ALOHA packet broadcast channel assumed that, when any part of two or more packets overlap, all packets involved in the collision must be retransmitted. In reality, there is at least some probability that one of the packets involved in a collision will be sufficiently strong to capture the receiver and be received accurately. If this were the case, not every packet involved in a collision would have to be retransmitted, which would reduce the apparent interference and increase the channel throughput at any level of traffic.

a "quieting" period between the high-powered forward link and the low powered subscriber return link.

MPR asserts that NWN is 2.7 times more spectrally efficient than PIMS

> "The proposed MTel NWN system is 2.7 times more spectrally efficient than the equivalent PageMart PIMS system, when considering the bits delivered per frequency domain, time domain and space domain."

PIMS' capacity correctly stated is as proposed to the Commission. Taking into consideration the MPR redesign of the PIMS system, it is not surprising that MPR ends up with NWN being 2.7 times more spectrally efficient. However, lets look at the facts causing such a dramatic change of estimate to that provided by PageMart in their PIMS Rulemaking document:

PIMS Capacity Factors Considered by MPR and PageMart

Factor	MPR	PageMart	Comment
Poll Channel Capacity (Transactions/Hr) @ ________bps	3,000 @4,800	112,700 @4,800 225,400 @ 9,600	MPR incorrectly assumed PIMS requires more than one codeword to respond.
Office & Building Cells	None	Represents 2/3 System Capacity	MPR arbitrarily disregarded PIMS throughput capability using office/building cells.
Geographical Cell Reuse	9 cell Reuse	4 Cell Reuse	MPR elected to ignore current cellular reuse technology by their own cited authority, Dr. Lee.

What is difficult to understand, is how a simulcast system such as NWN in a major MSA can expect to be as efficient as a cellular system including office and building level reuse capability. MPR's approach was to deny the possibility of office and building cells, reduce the throughput of the polling channel by a factor of 37.5 (even when the MPR author recognized that it didn't have to function the way MPR assumed) and to require PIMS to use a 9 cell reuse plan that is 3 times less efficient than their own cited cellular authority advocates.